Computational Photography

George Legrady © 2022
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Definition of Computational Photography

Computational photography refers to digital cameras where computers are integrated into the image-capture process within the camera

- Examples of computational photography results include in-camera computation of digital panoramas,[6] high-dynamic-range images, light-field cameras, and other unconventional optics
- Sensing in other electromagnetic spectrum

3 Leading labs in the mid-2000s:

- Computer Graphics Lab, Stanford University/, *Marc Levoy*
- Camera Culture, Media Lab, MIT/ *Ramesh Raskar*
- Computer Vision Lab (CAVE) Columbia University, *Shree Nayar*

https://www.mat.ucsb.edu/~g.legrady/academic/courses/11s594r/compphoto.html

Description of Imaging Processes through Computational Photography

Photons > Lens (optics) > Sensor > Software Processing > Image

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Multiple image capture averaging
Image exposure/contrast correction
Focus & other correction
Composition recommendation
Etc.

From Shree K. Nayar, Columbia University

Digital Photography	Computational Photography	Computational Imaging/Camera	Computational Image Sensor
Image processing applied to captured images to produce "better" images.	**Processing of a set of captured images to create "new" images.**	**Capture of optically coded images and computational decoding to produce "new" images.**	**Detectors that combine sensing and processing to create "smart" pixels.**
Examples: Interpolation, Filtering, Enhancement, Dynamic Range Compression, Color Management, Morphing, Hole Filling, Artistic Image Effects, Image Compression, Watermarking.	**Examples:** Mosaicing, Matting, Super-Resolution, Multi-Exposure HDR, Flash and No-Flash, Light Field from Multiple View, Structure from Motion, Shape from X.	**Examples:** Coded Aperture, Optical Tomography, Diaphanography, SA Microscopy, Integral Imaging, Assorted Pixels, Catadioptric Imaging, Holographic Imaging.	**Examples:** Artificial Retina, Retinex Sensors, Adaptive Dynamic Range Sensors, Edge Detection Chips, Focus of Expansion Chips, Motion Sensors, Neural Network Chips.

Shree K. Nayar, Director (lab description video)

- Computer Vision Laboratory
- Lab focuses on vision sensors; physics based models for vision; algorithms for scene interpretation
- Digital imaging, machine vision, robotics, human-machine interfaces, computer graphics and displays [URL]

- **Refraction** (lens / dioptrics) and **reflection** (mirror / catoptrics) are combined in an optical system, (Used in search lights, headlamps, optical telescopes, microscopes, and telephoto lenses.)

- Catadioptric Camera for 360 degree Imaging

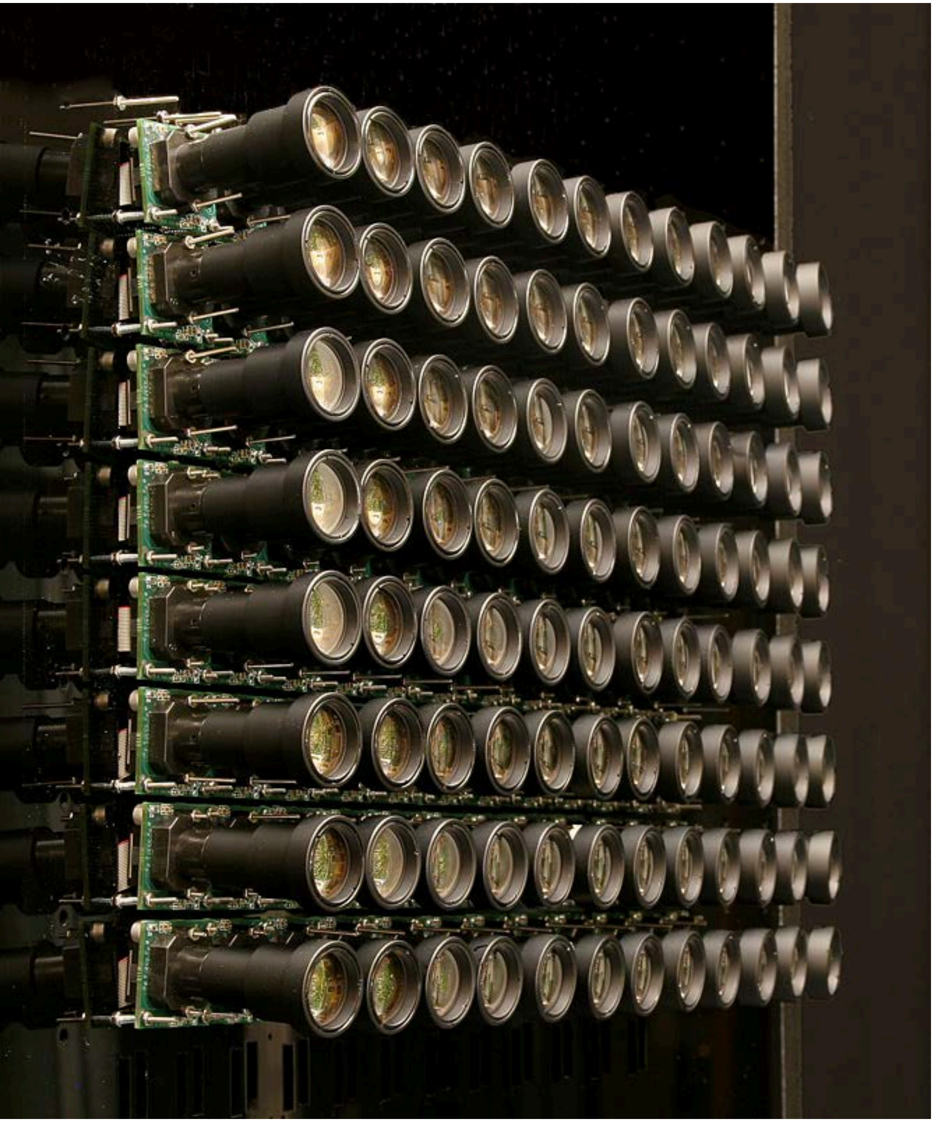
(Catadioptric: refraction & reflection combined)

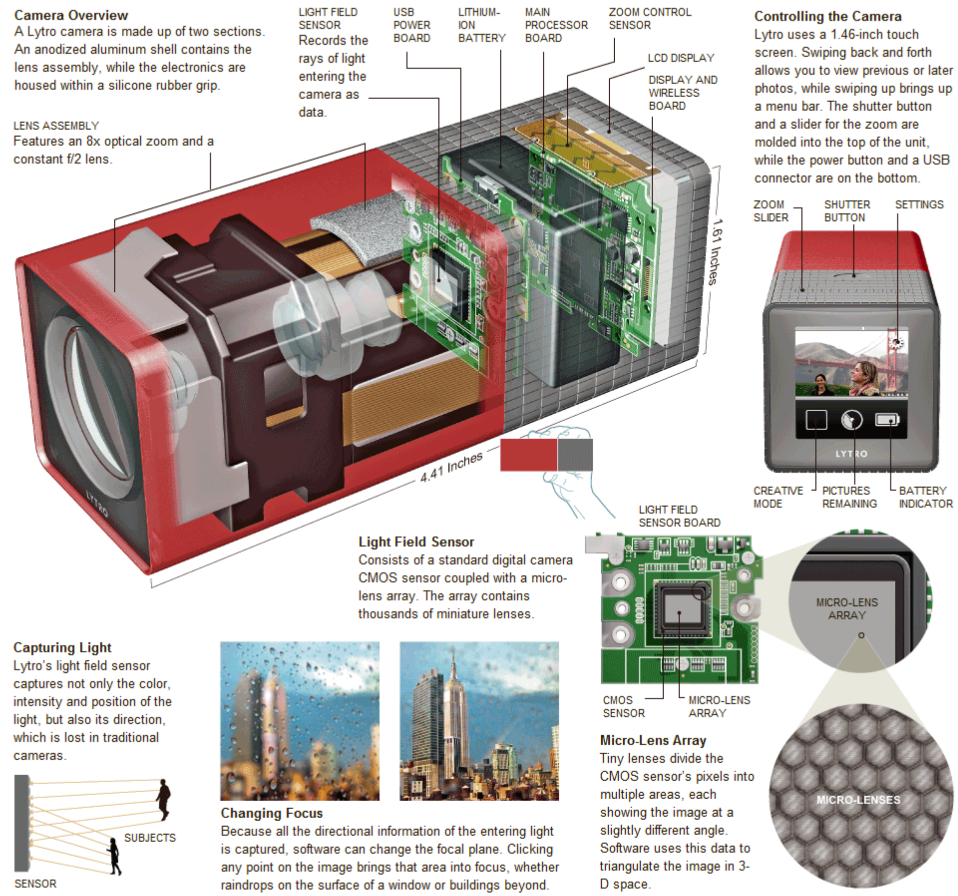
- Reflector | Recorded Image | Unwrapped
- 360 degree cameras [Various projects]

Light-Field Cameras, Computer Science Lab, Stanford (Marc Levoy)

- Light fields were introduced into computer graphics in 1996 by Marc Levoy and Pat Hanrahan. Their proposed application was *image-based-rendering* - computing new views of a scene from pre-existing views without the need for scene geometry.
- Light field: Returns the amount of light traveling in 3D space. Add time or multiple lenses – extends to 4D (Gershun, 1936)
- Different point of views allows multifocus depth

Marc Levoy, Computer Science Lab, Stanford



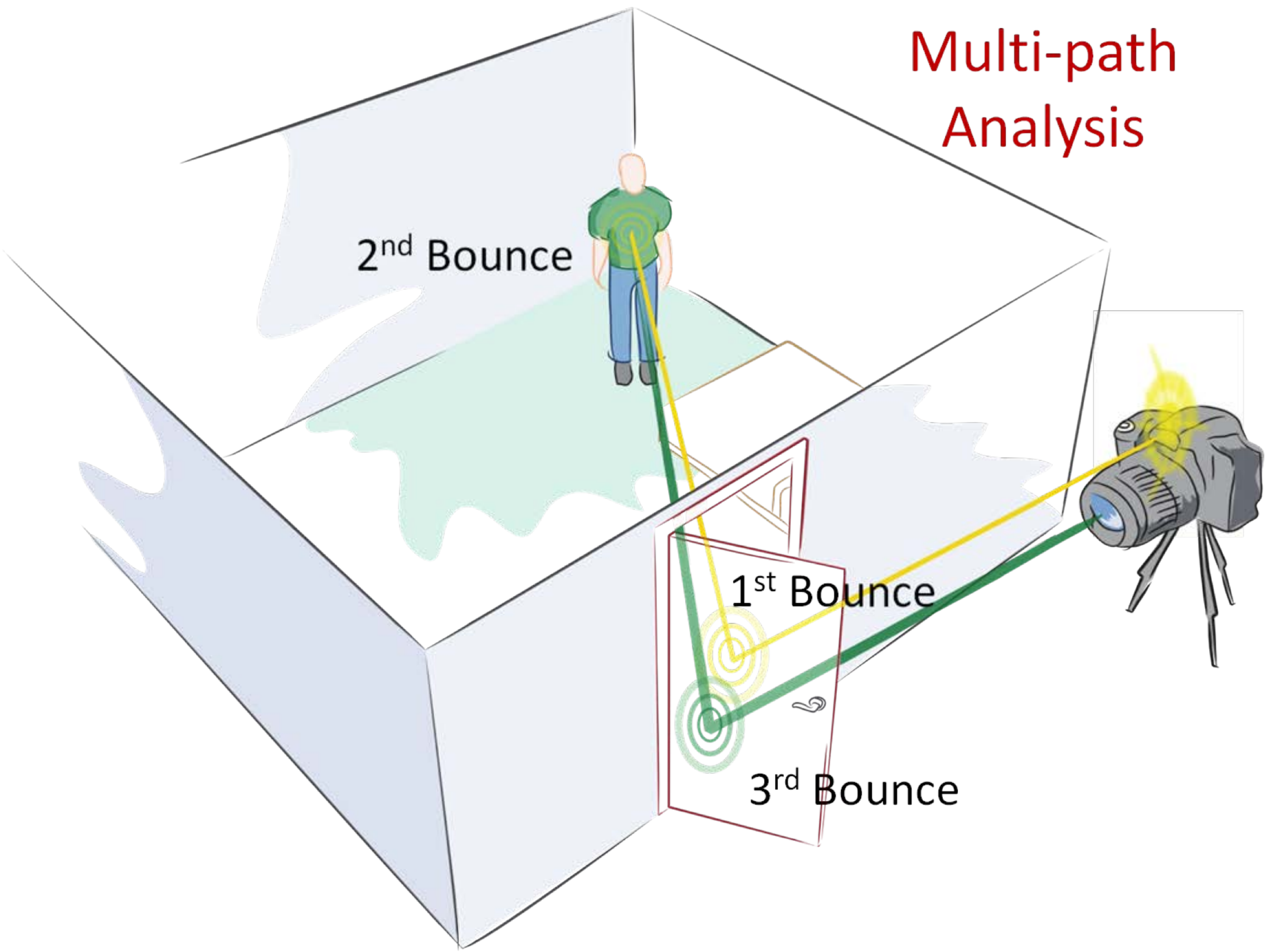


http://graphics.stanford.edu/projects/lightfield/

Ramesh Raskar, Director [lab projects]

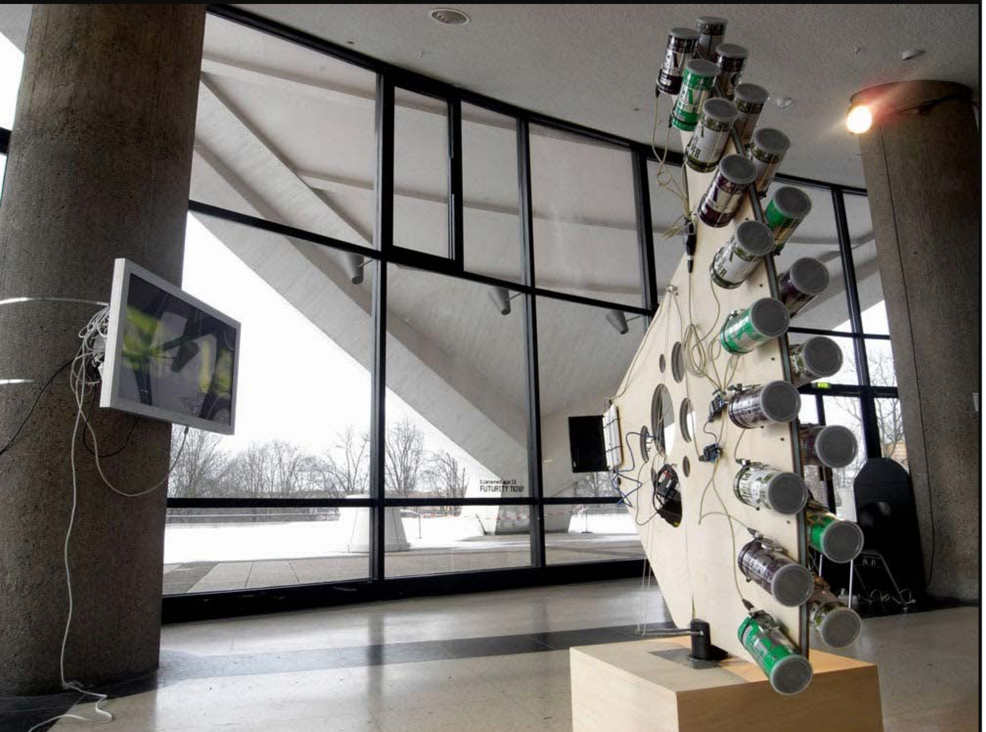
- More than a billion people now using networked, mobile cameras: Rapid evolution in activities based on visual exchange
- Our goal is to go beyond post-capture software methods and exploit unusual optics, modern sensors, programmable illumination, and bio-inspired processing
- Keynote: 2:00/5:07 Biology to Wishlist - [video]

“Femto Camera”, Ramesh Raskar, Camera Culture, MIT Media Lab



- To compute the geometry of the object inside the room the user directs an ultra short laser beam onto the door and after the first bounce the beam scatters into the room
- The light reflects from objects inside the room and again from the door back toward the transient imaging camera
- An ultra-fast array of detectors measures the time profile of the returned signal from multiple positions on the door

Wifi Camera



Visualizing Wifi using the Wifi Camera

***Somlai-Fischer, A.* [1], *Sjölén, B.* [2] *and Haque, U.* [3]**
1) *Aether Architecture, Budapest, Hungary. E-mail: adam@aether.hu*
2) *Automata AB, Stockholm, Sweden. Email: bengt@automata.se*
3) *Haque Design+Research. Email: info@haque.co.uk*

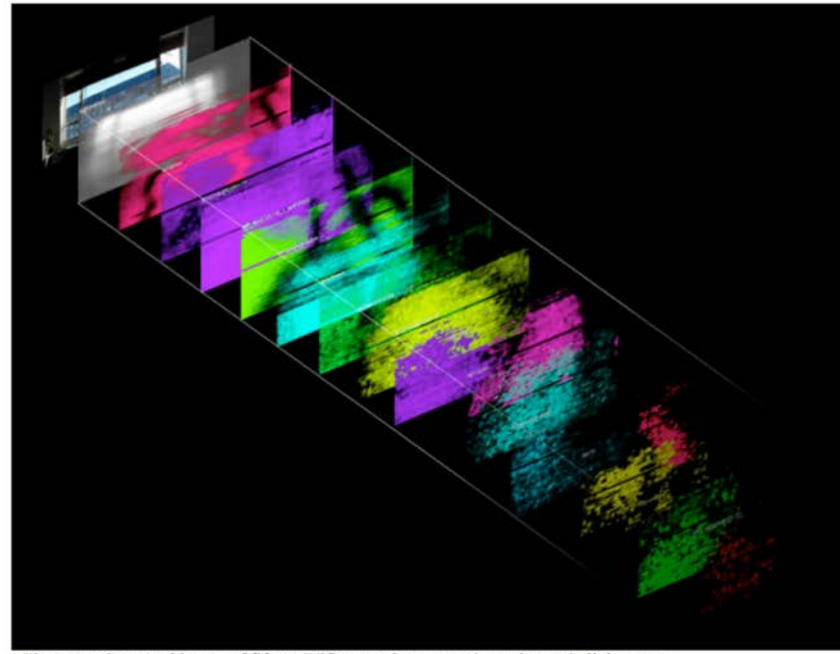


Fig.1. Amalgamated image of fifteen Wifi networks permeating a domestic living room.

Fig.2. Equipment

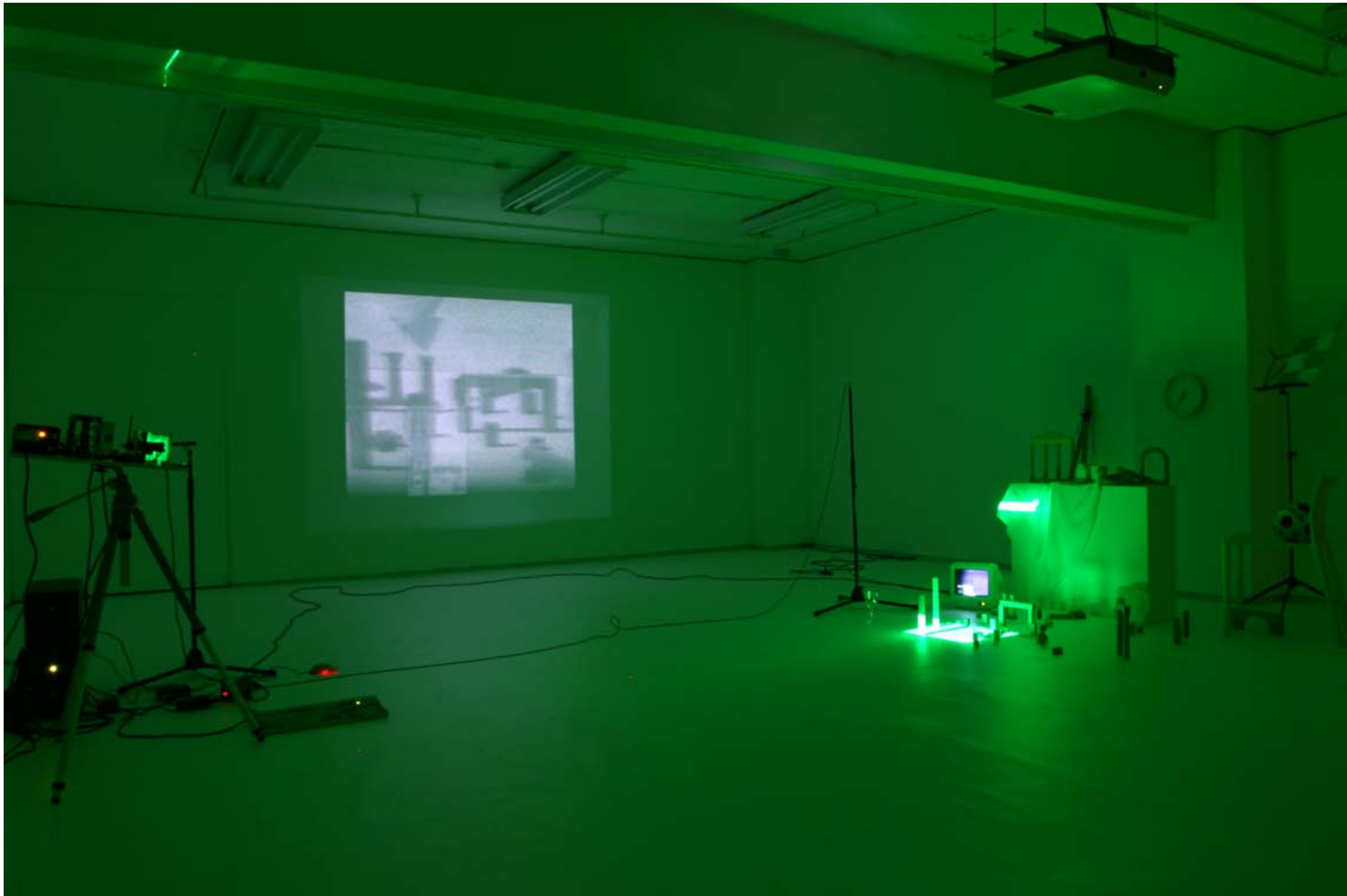
Fig.3. View of window showing two networks coming through

These images were created using a "Wifi Camera" custom designed by Somlai-Fischer, Sjölén and Haque (information available at <http://wificamera.propositions.org.uk/>). It makes a use of a directional 2.4Ghz wifi antenna mounted on servos scanning an environment at varying resolutions, measuring signal strength of all present networks to generate an image of the wifi "view" of the space. A light sensor is mounted on the antenna in order to generate a visible-light image that confirms precise orientation.

https://www.youtube.com/watch?v=621n4Mhr_L0

Ruska's Room, Masaki Fujihata

- Creating an image without optical lens – Ruska's Room [video]



Arts & Engineering Conundrum

- **Technological Push**: Engineering research in many cases prioritizes advancing knowledge and technology for the sake of research
- **Aesthetic Pull**: Artists develop technologies driven by project demands
- The engineers will participate only if research is advanced, otherwise they see it as “service” or distraction
- The challenge for the artists is to identify and articulate how an artistic context can advance research

Links: http://legrady.mat.ucsb.edu/academic/courses/13s265r/index.html

- Frankencamera (into a Leica camera)
- Lytro , LightField (Levoy Lab at Stanford)
- LightField Video (Debevec Lab Campanile/Matrix)
- View Synthesis, (Snavely Lab, Cornell)
- Femto (Ramesh Raskar Camera Culture, MIT)
- Computer Vision Lab, Columbia University
- PhotoSynth (Obama inauguration)
- GigaPixel (Photo enlargement Software)

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